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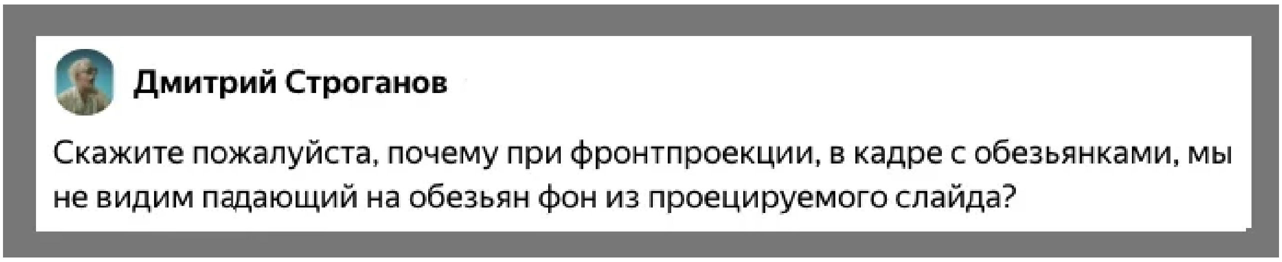
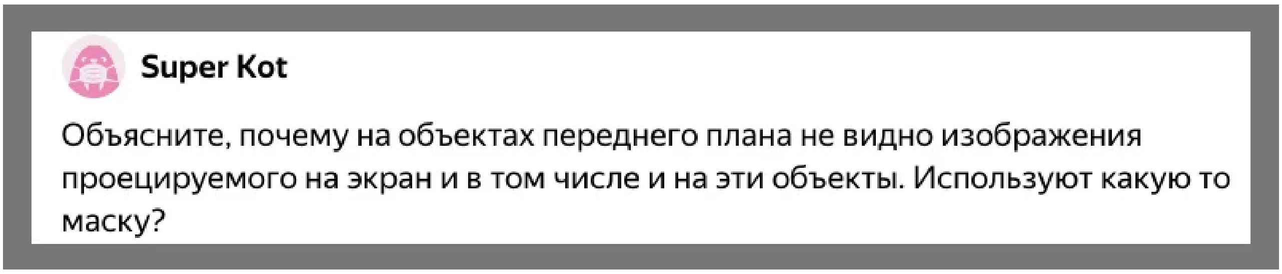
19 min read

86. If NASA used front projection in lunar images, why can't the light from the slide projector be seen on the spacesuits?

As soon as I published the article on Zen "Did Stanley Kubrick film the moon landing? "about the use of **front projection** in lunar images, when puzzled questions immediately appeared. Their meaning was as follows: if a slide projector with an image of a lunar mountain shines from the front on the actors and the camera shoots from the front, then why the actors and white spacesuits cannot see the light from slide projector?


Дмитрий Строганов

Скажите пожалуйста, почему при фронтпроекции, в кадре с обезьянками, мы не видим падающий на обезьян фон из проецируемого слайда?


Super Kot

Объясните, почему на объектах переднего плана не видно изображения проецируемого на экран и в том числе и на эти объекты. Используют какую то маску?

Someone suggested that some cunning mask could be used in the frame (it was not there), someone began to develop the thought further and suggested that light is not visible on dark objects (in Kubrick's film these are dark monkeys), but on In a light-colored spacesuit, the projector light will probably be noticeable (in fact, it will not be noticeable).

Ivanov Alexey

Техника проецирования очень интересная, но очевидно, что в данной задаче она не сработает.

Предполагаемый проектор находится перед объектами съемки, значит на все эти объекты будет проецироваться изображение фона.

Почему не видно этого изображения у Кубрика? Потому что актеры, игравшие обезьян были в черных костюмах, имитирующих шерсть. На черных костюмах это изображение не видно.

Do all people ask such questions sincerely? Do they really want to understand the intricacies of the process? Or they are simply trying to shield the American lunar scam, claiming that the Americans could not have front projections in the lunar frames, because the lunar mountain projected from the slide projector would be visible on the astronaut's white spacesuit.

Be that as it may, readers want to understand the intricacies of the front projection method. We will now be happy to answer these and other questions that arise along the way.

Ivanov Alexey

Но скафандры астронавтов были белые. Более того, это был материал с высоким коэффициентом отражения. Практически такой же, как и "скотч-лайт".

I'll start with the last question, more precisely, the statement that the reflection coefficient of the spacesuit is the same as that of the scotch light. I will disappoint the author. A white spacesuit has a higher reflectance. Scotch light - aka gray. Here in the photo, a person is standing against the background of a reflective screen. The graphic on his T-shirt is in white paint, and you can see that the Scotch Light screen behind him is darker than the white lettering on the T-shirt.

Here is another photo where you can see an unrolled roll of Scotch tape made by 3M. He is completely gray. You can see that the scotch tape has a lower reflectance than the white material.

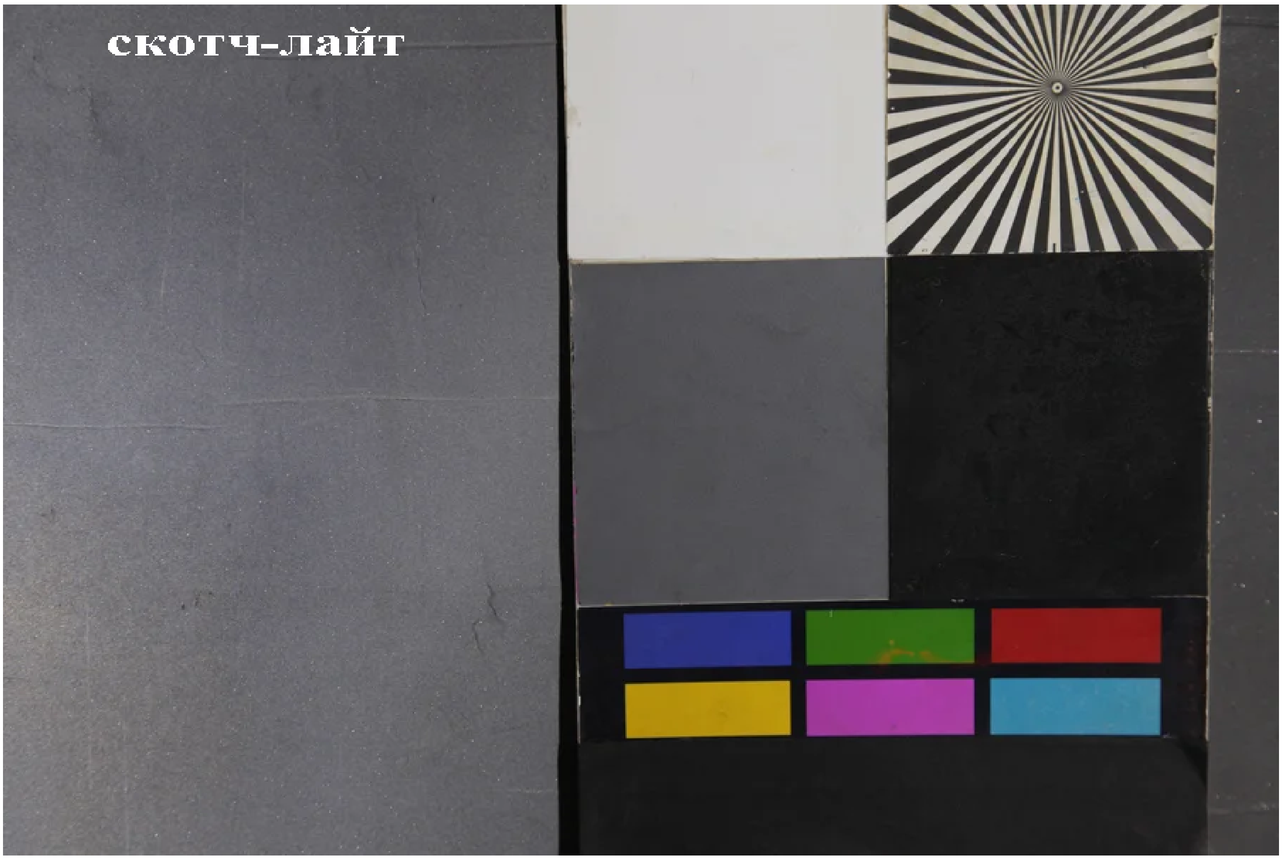
Reflection coefficient (we pay special attention to this) is defined as the **integral** percentage of light reflected by the material in all directions. When the reflectance is determined in the laboratory, the test material is placed inside a white sphere and the total percentage of reflected light is determined with a photometer.

Spectrophotometer SF-18. On the left - a white sphere inside with round windows for measured samples.

However, there is another quantity **- the luminance factor** , which is defined as the percentage of light reflected in a **given direction** .

White paper (white fabric or a white polyvinyl screen in a movie theater) has a luminance factor that does not depend on direction - the white material scatters light equally in all directions. This reflection is called diffuse. If I aim the spotlight at a white surface, the light will be evenly reflected in all directions. And from whatever angle I look at the illuminated sheet of paper, it will be perceived **equally** white from any direction.

Scotch light behaves quite differently. In diffused light, it looks gray, about the same **brightness** as the mid-gray field on the test bar on the right.



Left - Scotchlight screen, right - gray scale.

Left - Scotchlight screen, right - gray scale.

But if you take a picture with a flash with a camera, for example, a cell phone, the brightness of such a screen will increase many times. The screen will turn "blinding" white.

When using a directional flash light, the brightness of the scotchlight is increased many times.

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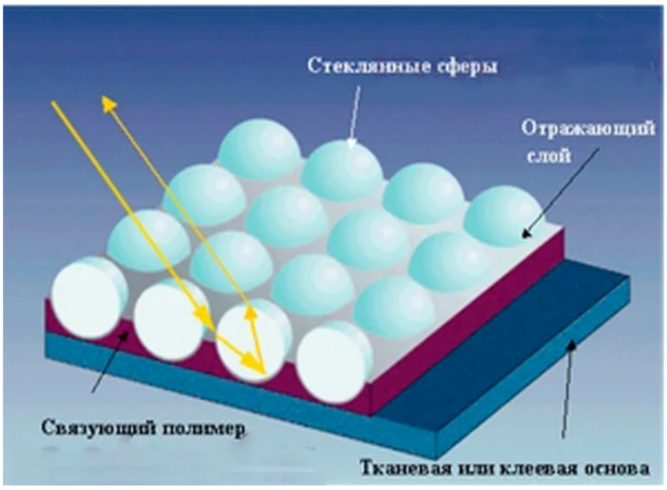
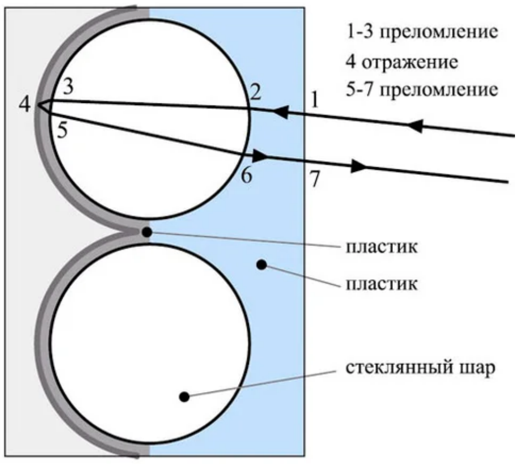
This is due to the fact that almost all the light hitting the screen from the flash is not scattered in all directions, but being reflected in a glass ball, like from a mirror, returns back to the light source.





Thanks to the spherical surface, the light beam returns to where it came from.

Thanks to the spherical surface, the light beam returns to where it came from.

And since the flash on the cell phone is located very close to the lens, almost all the reflected light is directed back to the lens, and the screen illuminated by the flash turns out to be dazzling white in the photo.

The flash on the cell phone is close to the lens.

The flash on the cell phone is close to the lens.

And the gray and white fields, next to the scale, scatter light diffusely in all directions, and the amount of light that returns back to the lens is negligible.

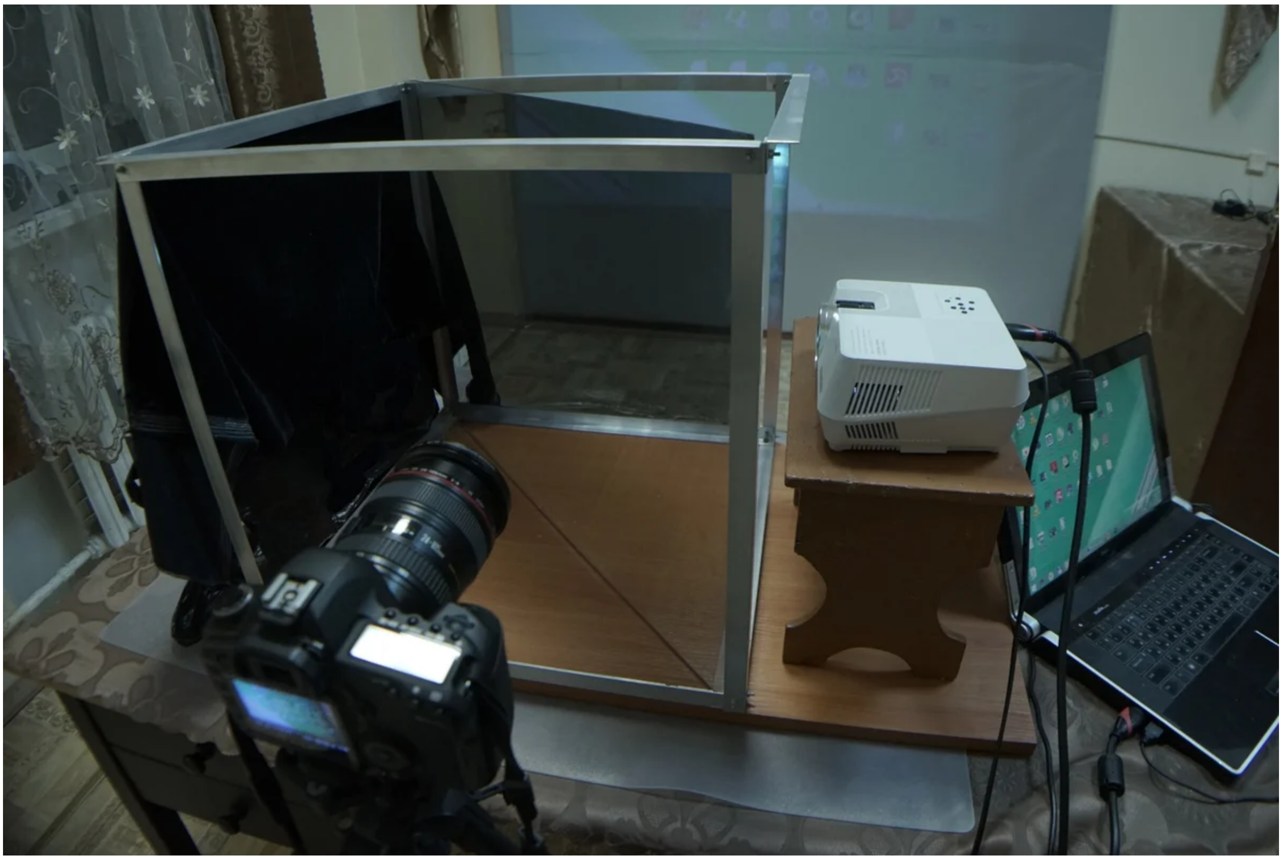
Imagine that you are letting out a "sunbeam" with a mirror. And then, instead of a mirror, you take a circle of white paper and try to release a "sunbeam" with paper. How many

times will **the brightness coefficient of the** "sunbeam" change ? I made such measurements, only not with the sun, but with a lighting device in the pavilion, comparing the brightness of the device, which was reflected in the mirror, and the brightness of a white sheet of paper lying next to it. It turned out more than 120 times. (Below I will demonstrate the results of measuring the brightness of white paper and an adhesive tape screen.)

If we evaluate the integral reflection coefficient, then it is possible that the white sheet and the mirror will have the same - the white paper will reflect **all the** light that has fallen on it, and the mirror will also reflect **all the** light that has fallen on it. **The integral** reflection coefficients will be the same. But **the brightness coefficients** will be different : the paper reflects light slightly in all directions of the solid angle, and the mirror reflects all the incident light strictly in one direction.

If you follow the beam of the "sunbeam" coming from the mirror, you will see a dazzling brightness. But as soon as you move a little away from the beam, the brightness will immediately disappear. This is approximately how the scotch-light material works. It is a screen made up of tiny mirrors. To see the maximum screen brightness (and the brightest slide on this screen), the observer needs to stand strictly along the projector beam. The eye of the observer should be close to the lens of the slide projector and look in the direction where the projector beam is directed, at the screen.

When you start moving your eye as close as possible to the lens of the slide projector, you will block the light with your head. If you try to put the movie camera right next to the projector lens, then the movie camera, of course, will block the entire light flux. They came up with a simple scheme: put a semitransparent mirror in the path of light at an angle of 45 ° with a reflection coefficient of 50%. The camera shoots through this mirror.



On the left is a camera, on the right is a video projector (with a white body), between them is a semitransparent mirror at an angle of 45 °. In the back is a scotch-light screen.

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The observer, who stands to the side of the camera, sees that the scene is barely visible on the scotch-light screen. And only when he gets into the place of the camera, he will notice that the brightness of the screen flashes sharply.

The light from the projector reaches the mirror, 50% of the light is reflected, changes direction by 90 °, hits the screen and, being reflected, goes in a straight line, directly into the lens of the shooting camera. The distance from the projector lens to the mirror and from the mirror to the camera lens are the same.

The diagram of the movement of the beam from the projector to the camera during front projection.

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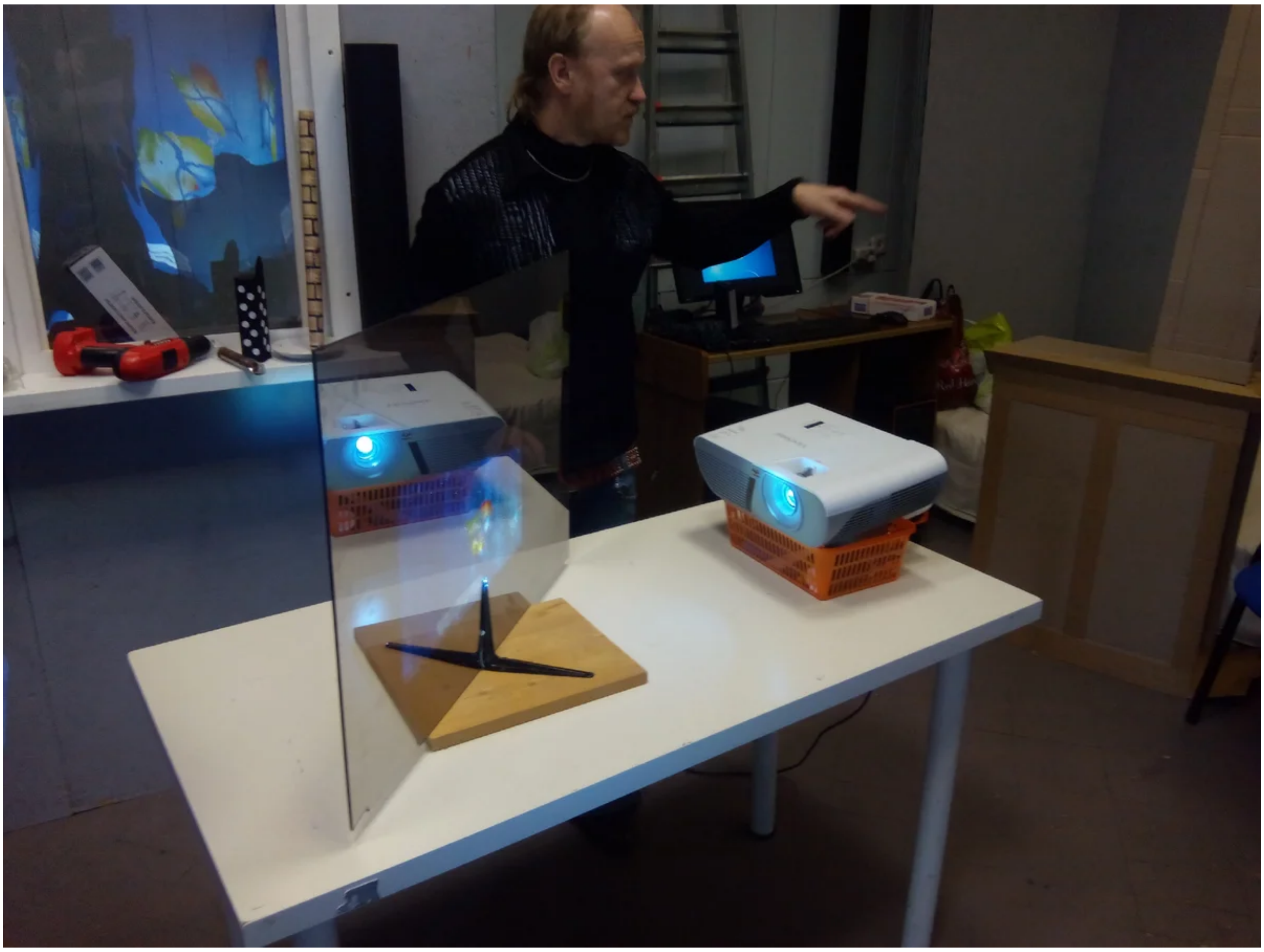
Of course, not all of the light from the projector is reflected by the mirror, 50% of the light goes (to the left) in a straight line through the translucent mirror, and this part of the light is not used in any way. This stream of light is extinguished by black velvet. If there were no black velvet, then the camera in the translucent mirror would see the reflection of the left wall of the room (and even illuminated by the projector), and this is not necessary at all - the camera should only see what is directly in front of it on the screen. By the way, in Wikipedia, on the page dedicated to front projection, they forgot to draw black velvet, and this is a fundamentally important omission. I don't know if I should correct the drawing on Wikipedia, or let it remain with errors? There, by the way, another mistake was made - with a shadow on the screen. It should not be translucent, but completely black.

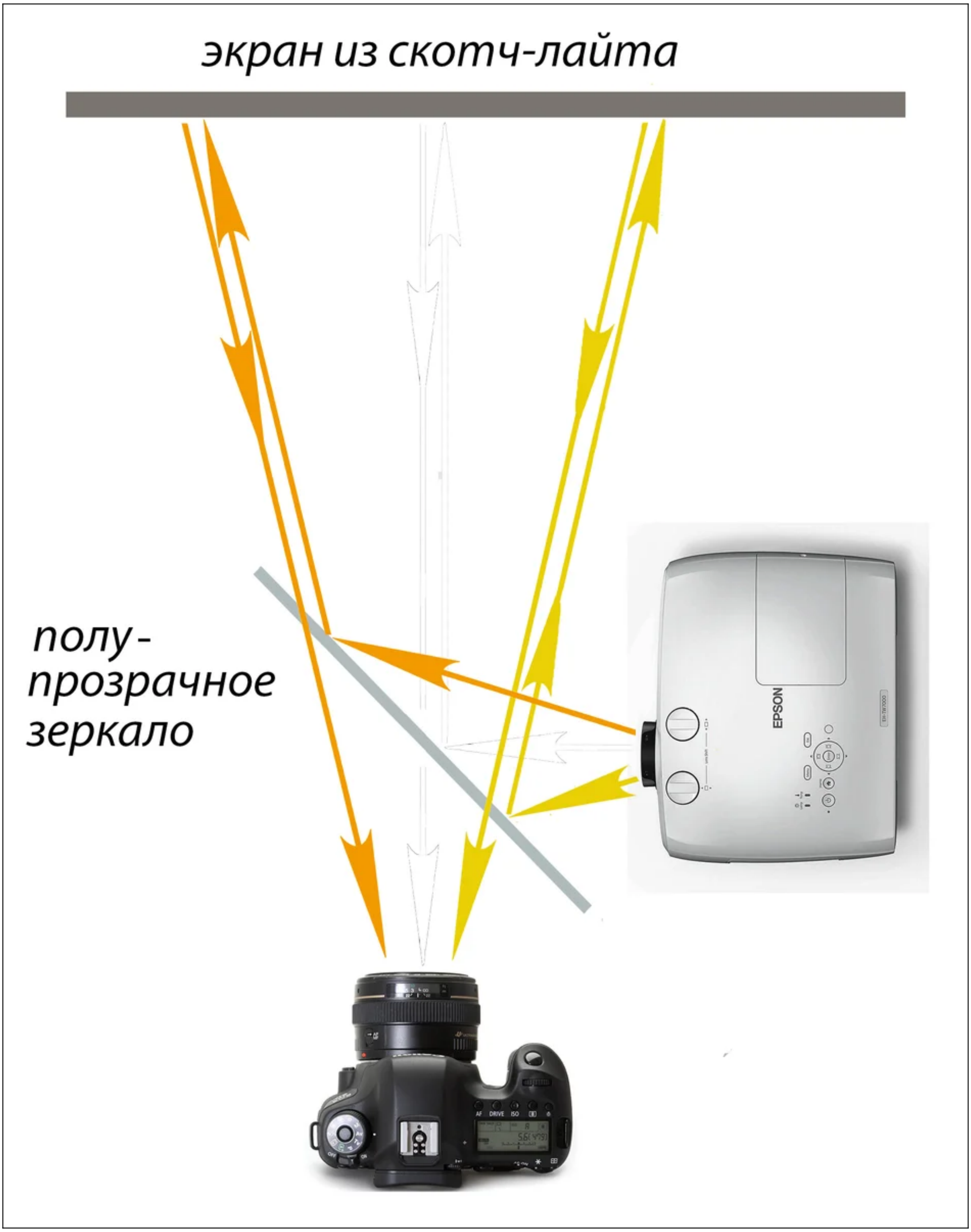
Let's clarify that the light from the projector falls on the semitransparent mirror not in the form of a point, but in the form of a rectangle (trapezoid).



The light from the projector falls on a trapezoidal translucent mirror.

The light from the projector falls on a trapezoidal translucent mirror.

Therefore, not only the central, but also the edge rays should be added to the ray pattern. And all these rays, reflected from the screen, converge into a spot similar in size to the glowing projector lens.



Beam convergence pattern after reflection from a reflective screen

Beam convergence pattern after reflection from a reflective screen

I guess that my dear reader is already impatient to find out how many times the brightness of the screen will increase if we replace the traditional white canvas with a scotchlight? I have carried out such measurements. Instead of a camera, I put a brightness meter at the point where the reflected rays are collected (in fact, this is not a point, but a luminous spot equivalent to the lens). This was our very first experiment, and instead of a translucent mirror, a regular window glass was used, which reflected 12% of the light.

Measurement through the glass of the brightness of the scotchlight and the white field on the scale. The projector is on.

Measurement through the glass of the brightness of the scotchlight and the white field on the scale. The projector is on.

On the back, behind a gray 4-field scale, was the scotch-light material. The measurement was carried out by a professional camera operator "Asahi-Pentax", the measurement angle was 1 °.

Yarkomer Asahi-Pentax for cameramen.

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After fixing the luminance gauge, the overhead light in the room was turned off and an accurate measurement was made.

Measuring the brightness of the white surface and the surface of the scotchlight.

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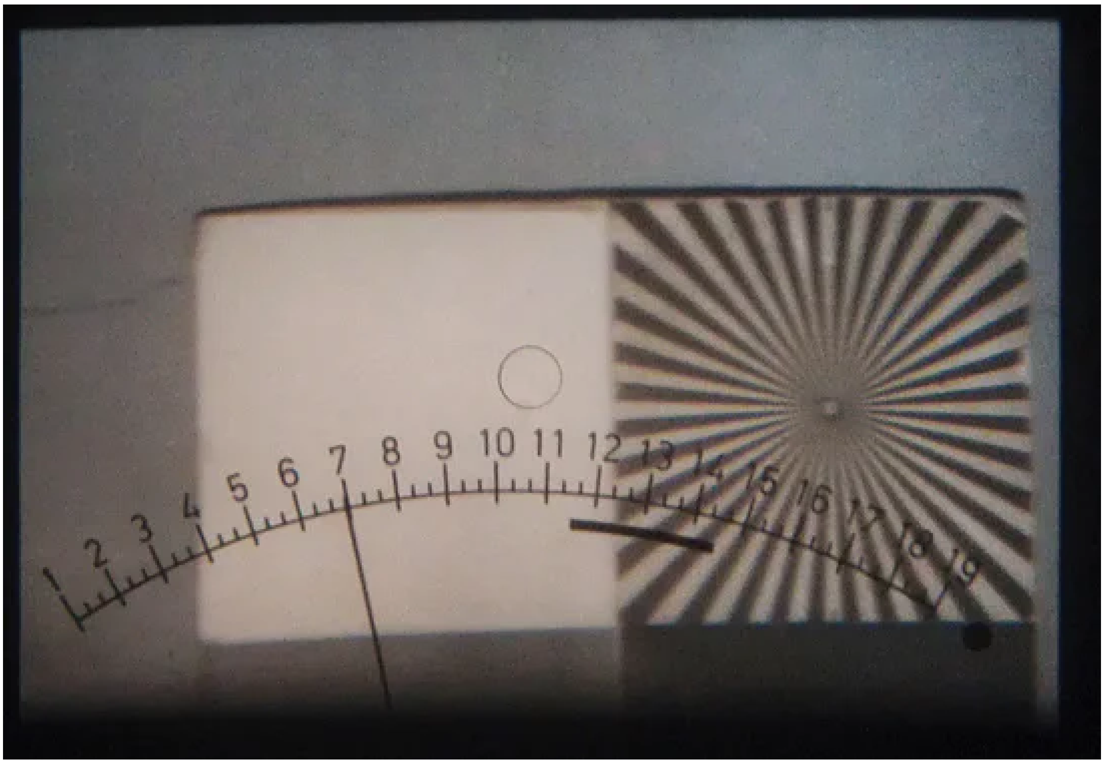
If you look through the eyepiece of the instrument, you can see a scale from 1 to 19 EV (exposure value) and a small circle in the center, it indicates a 1 ° metering angle. A difference of one EV unit corresponds to a 2-fold change in brightness, or, as they say, 1 stop.

Initially, we measured from the lateral direction, it was an angle of 20 ° from the perpendicular. As you understand, for a diffuse white field, small deviations from the normal do not matter when measuring. The white field had a brightness of 7 EV (see picture), and the scotchlight looked 2 stops darker (5 EV).



Measuring the brightness of the white field at an angle of 20 ° from the perpendicular. Scotch tape looks noticeably darker than the white field.

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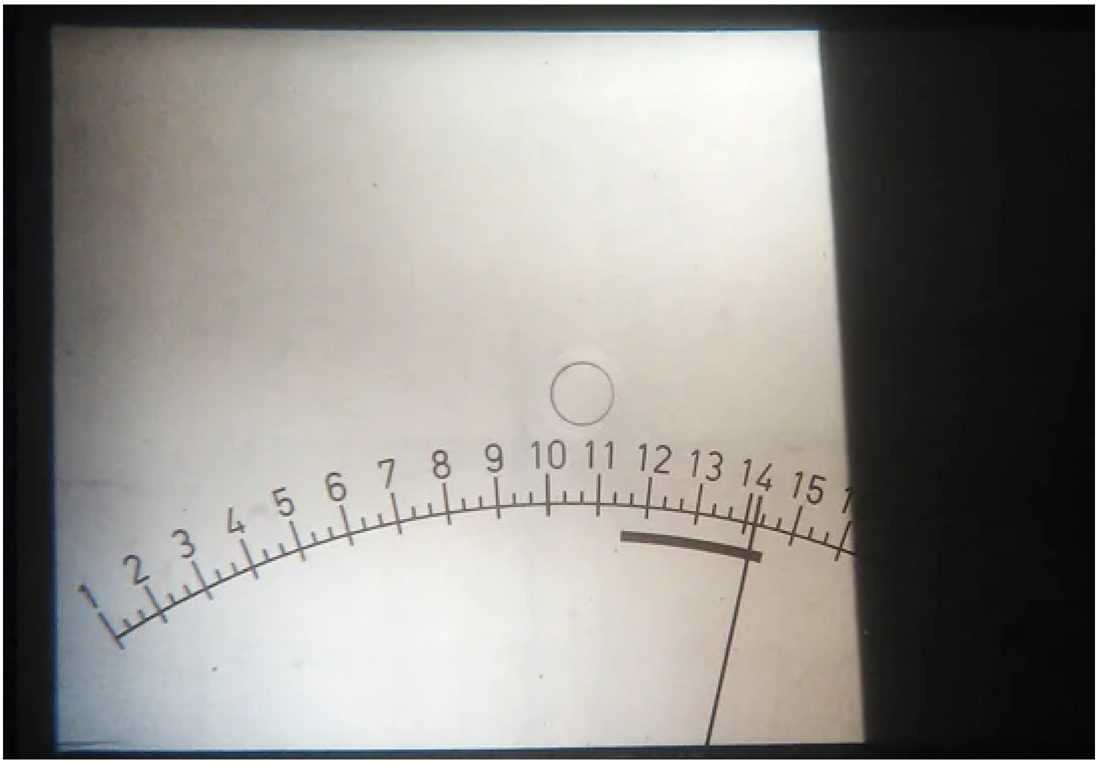
But as soon as we stood with the luminance gauge perpendicular to the screen, to the point where the light return lines intersect (at the height of the projector lens), the scotchlight screen immediately turned dazzling white - and so super-bright that next to it the white scale field (located to the right of the point measurement) began to appear black (next figure).



Maximum brightness of the scotchlight screen when measured perpendicularly. The dark part of the frame on the right - this is how the white field now looks.

Maximum brightness of the scotchlight screen when measured perpendicularly. The dark part of the frame on the right - this is how the white field now looks.

The luminance gauge values are gone for 14.2 EV. It is easy to calculate that compared to the white field (its brightness was 7 EV), the screen became brighter by 14.2 - 7 = 7.2 stops, or 2 to the power of 7.2, which is 147 times. Feel the difference? **When using a scotchlight screen, its brightness becomes about 150 times higher than that of a traditional white cinema screen!** This means that we can use a very weak lamp in the projector or, which is much more important for front projection, we can significantly increase the screen size.

You may ask: why are such screens, since they are so good, not used in cinemas? Yes, because such a high brightness can only be seen by one single person who is in the beam of the projector. For a viewer who is not strictly perpendicular to the screen, but looks at the screen slightly from the side, for example, at an angle of 20 °, the Scotch Light screen will appear 4 times darker than the white screen.

Nevertheless, there are people who put a reflective screen on the wall in front of the projector at home, and they were satisfied with this. On the internet you can findtests

comparing white and reflective screens . For example, here's a freeze frame from one such test.

Reflective screen - a strip over a white screen.

In our experiment, the brightness of the scotch tape increased 150 times compared to the white screen. But we measured a very narrow angle in the middle of the frame, and not the entire light rectangle that the slide projector gives on the screen. We know that any lens has a drop in brightness at the edges. Here, look, for example, at a frame from "A Space Odyssey", the corners of the frame are darkened, and this is especially noticeable in a bright sky:

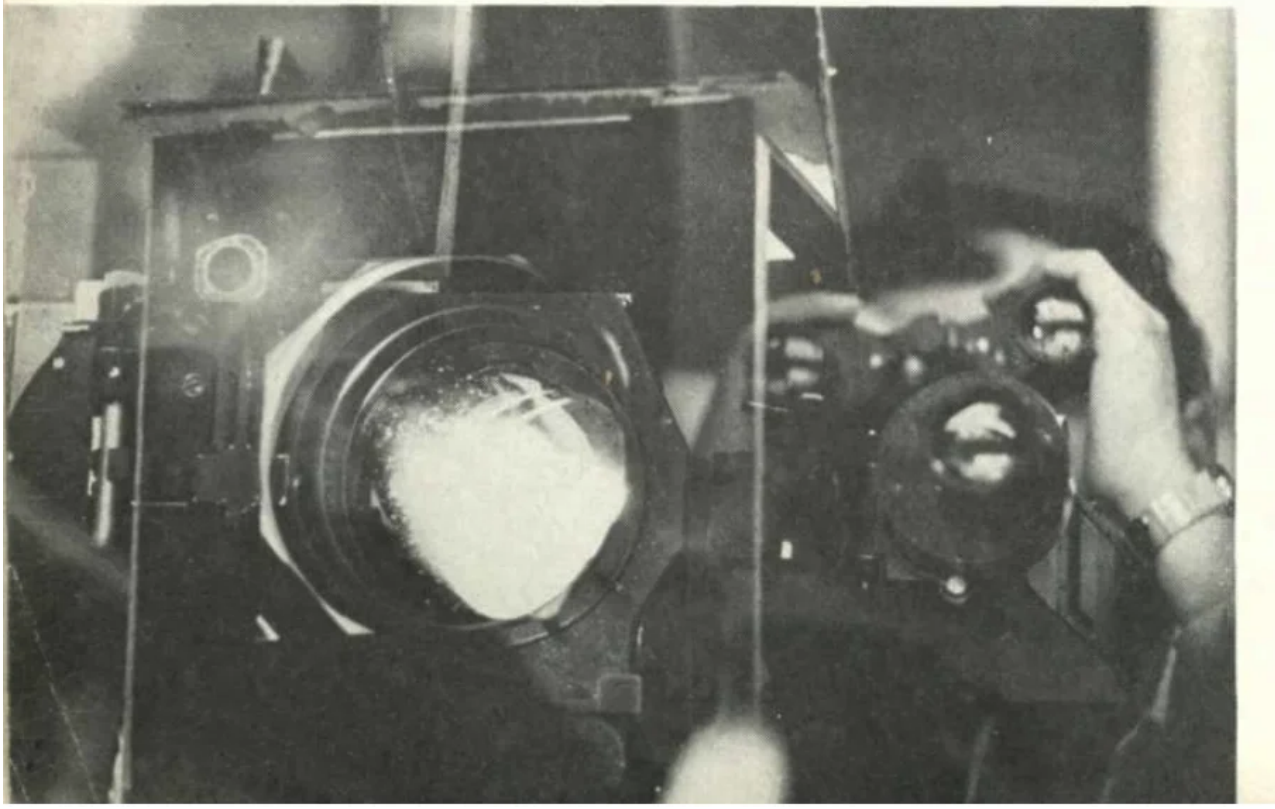
Stills from the film "2001. A Space Odyssey". Prologue "At the Dawn of Humanity".

Stills from the film "2001. A Space Odyssey". Prologue "At the Dawn of Humanity".

You probably ask: "Why, then, in NASA's" lunar "images, we do not see such a strong drop in illumination at the edges? So the fact is that the" moon frame "is not rectangular, but square! The edges are cropped! and such "moon pictures", where there is noticeable lightening in the center and darkening at the edges.

At the edge of a wide rectangular frame, the "gain" is reduced to 60-70 times. Due to thisan article on front projection in American Cinematographer mentions an average gain for a frame of 100 times.

On the set of "2001: A SPACE ODYSSEY," producer-director Stanley Kubrick uses binoculars to check fine focus on the vast front-projection screen. Special 3M material reflects 100 times the light falling upon the screen, provided that projector and film camera lenses are aligned on precisely the same axis. Kubrick wanted to use an 8 x 10 transparency for maximum sharpness, found there was no projector for it in existence, built his own.



The article indicates a "gain" of 100 times (100 times)

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How to dispose of such a gift of fate, a 100-fold increase in screen brightness? First, let's remember that with the old method, with keying, filmmakers were forced to use a screen with a width of 5-6 meters, no more. It is approximately **27 square meters** (6 meters wide

x 4.5 meters high). And they had to shoot at an open aperture, at 1: 2.3 or 1: 2.8. Because of this "open" diaphragm, a small depth of field (DOF) was obtained. The actor was in focus, and the screen in the background was already blurring a little. We gave such examples inprevious article .

Now it is possible to aperture by three stops (2.8 - 4 - 5.6 - 8) to a value of 1: 8, and get good sharpness in the frame, not only in the background, but also in the foreground. The depth of field (DOF) has increased markedly. In the prologue "At the Dawn of Humanity", a 6.3 diaphragm was used (intermediate between 5.6 and 8). And now, out of the 100-fold reserve, we have already used up 8 times (3 stops, if we shoot at aperture 8) or about 6 times (if we shoot at aperture of 6.3). We have about 16-17 times left in stock (100: 6 = 16.6). We will spend them to increase the screen area by 16 times.

The size of S. Kubrik's screen was 33.5 x 12 meters, the area was 402 sq. M. Compared to the rear projection screen, the area has increased by about 15 times (402: 27 = 14.9).

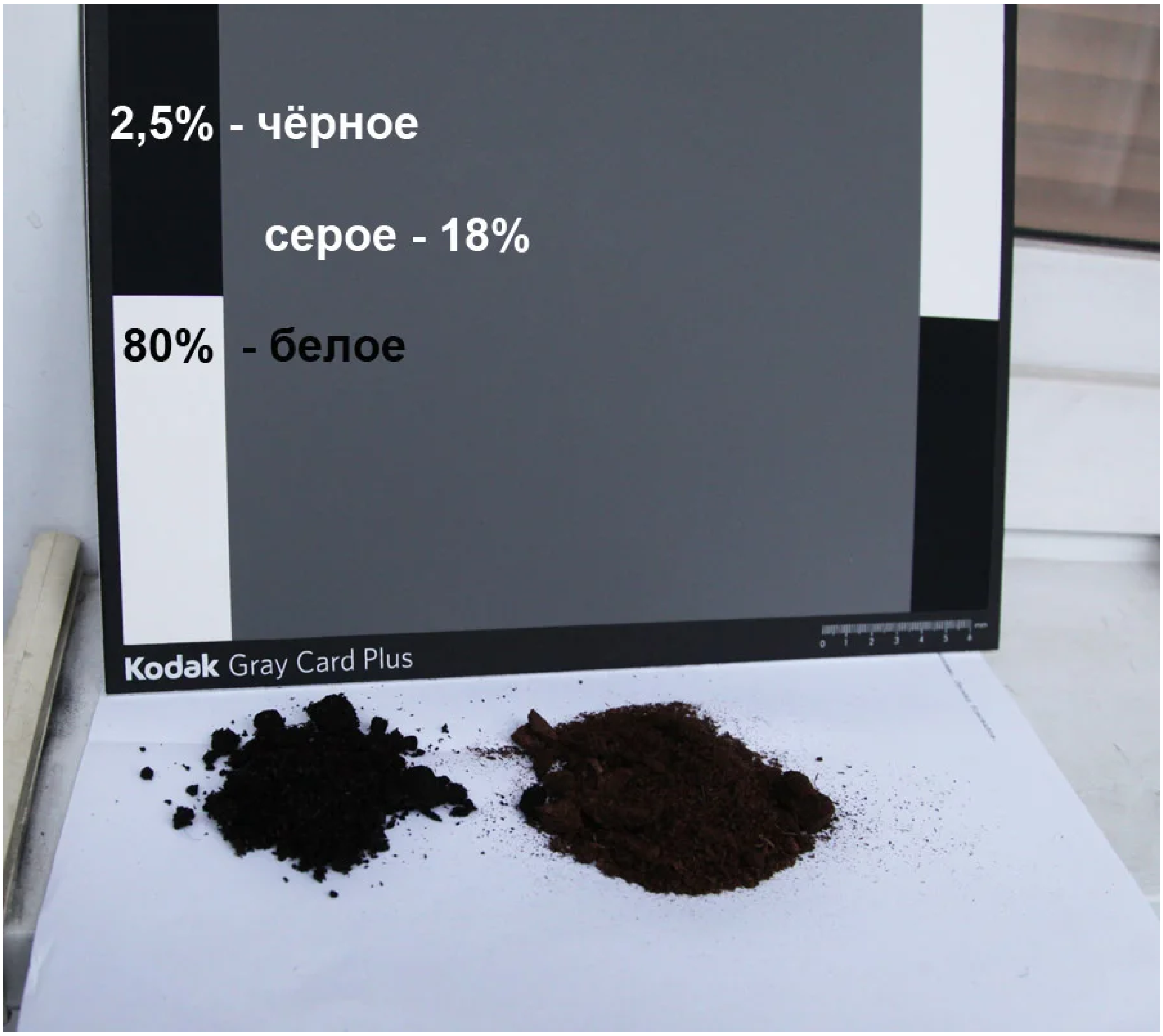
Thus, the transition from keying to front projection made it possible to increase the screen area by about 15 times and, at the same time, to aperture the lens by 3 stops.

And now, when we have described in detail all the stages of front projection, it is already possible to answer the question posed at the very beginning: Why is the light of the slad-projector not visible on the white spacesuits of astronauts?

Because the light is very weak from the projector. The main purpose of a slad-projector is to create a "picture" on a reflective screen. And for this screen, the luminous flux should be 100 times less than for a white screen. In other words, 100 times less light falls on the white material of a spacesuit from a projector than from a device that simulates light from the sun.

Wait, did I say 100 times less? No not like this! After all, not pure white light comes from the slide projector, a gray mountain is projected. And the gray mountain once again reduces the total light flow from the projector by a factor of five. Thus, light falls on the white spacesuit from the projector about 500 times less than from the "sun". And the width of the film is only 1:32 - 1:40 (five - five and a half steps). Photographic film is capable of transmitting an interval of brightness, if this interval does not exceed the range of 1:40.

For example, on a gray scale, a white field differs from a black one 32 times (80%: 2.5% = 32). The brightness interval is 1:32. It was considered the norm that photographic film should reproduce without distortion just such an interval from black to white, 1:32.



Standard gray scale "Kodak", brightness interval 1:32 (from white to black).

Standard gray scale "Kodak", brightness interval 1:32 (from white to black).

And if the interval is 100 or 500 times different, what will the film feel? Never mind. She simply will not notice such a faint light.

Let me give you an example of how we did practical shooting using the front projection method. This photo, which you see below, I have not edited or corrected anything. There is a camera on the right in the corner. He takes pictures through a translucent mirror. The signal from the camera is displayed on a small monitor above the camera and at the same time on a large TV. A weak video projector to the left of the mirror projects a view of

the castle. Half of the light from the projector passes directly onto the black sheet of paper, and the other half of the light is reflected by a translucent mirror and sent to a reflective screen in the background.

Mastering front projection at the Staircase film school. The camera is in the lower right corner.

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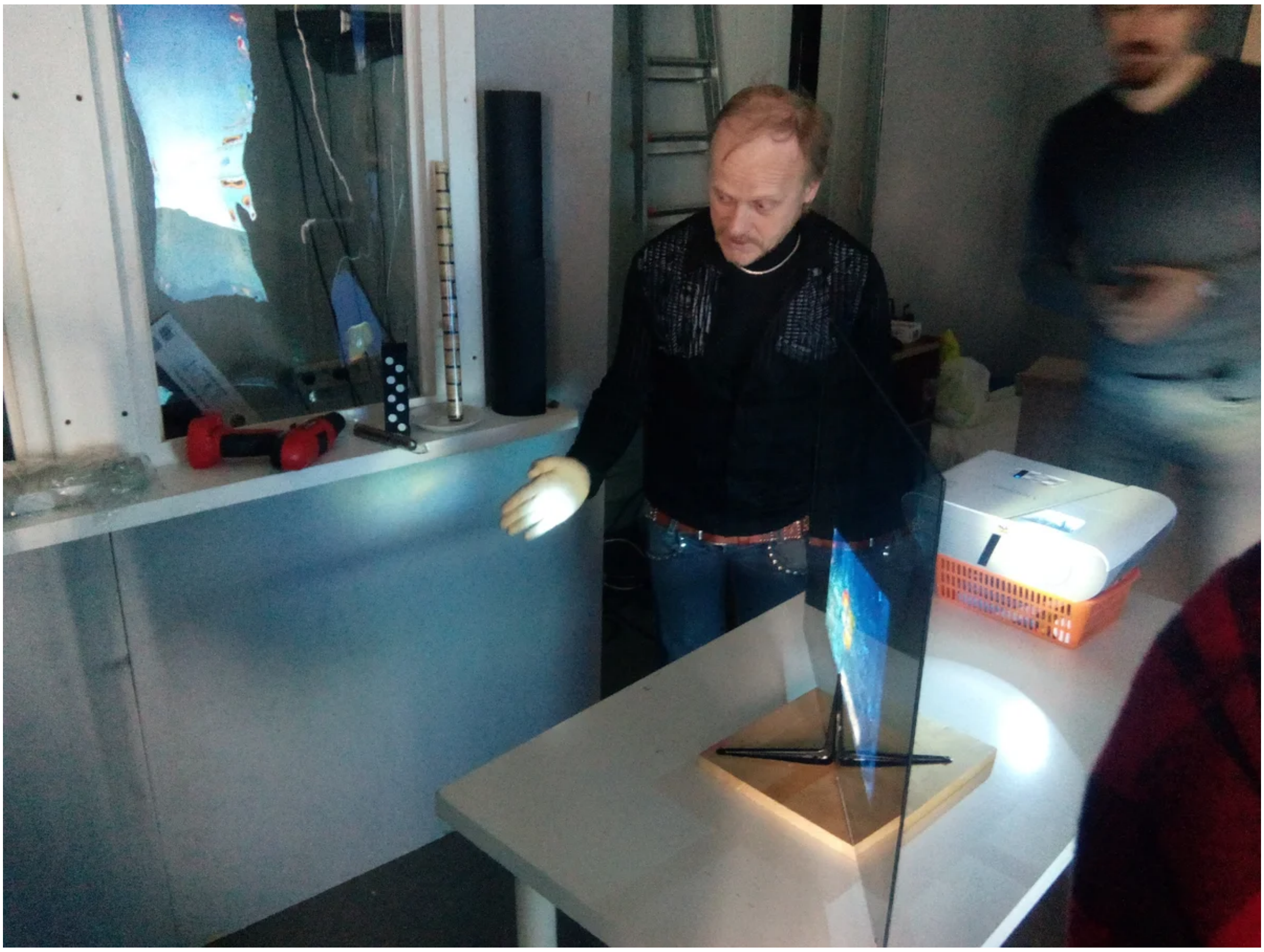
In addition, in order to color-match the face and background (the face is illuminated by an incandescent floodlight), an orange filter was attached to the projector, which brought the white light of the projector closer to the light of the incandescent lamp. This filter also attenuates the light from the projector. As a result, so little light hits the screen that even the eye cannot see anything there. And the observer, standing from the side (from where this picture was taken), also sees nothing. And only the camera, installed at the point of convergence of the reflected rays (bottom right), "sees" a medieval castle with a blue sky behind the guy.

A video projector shines on the reflective screen.

A video projector shines on the reflective screen.

In the next photo, we determine the place where the camera will be located - I show the light spot, where the rays reflected from the screen converge.



And here is what the camera, standing on the axis of the projector, saw as a result:

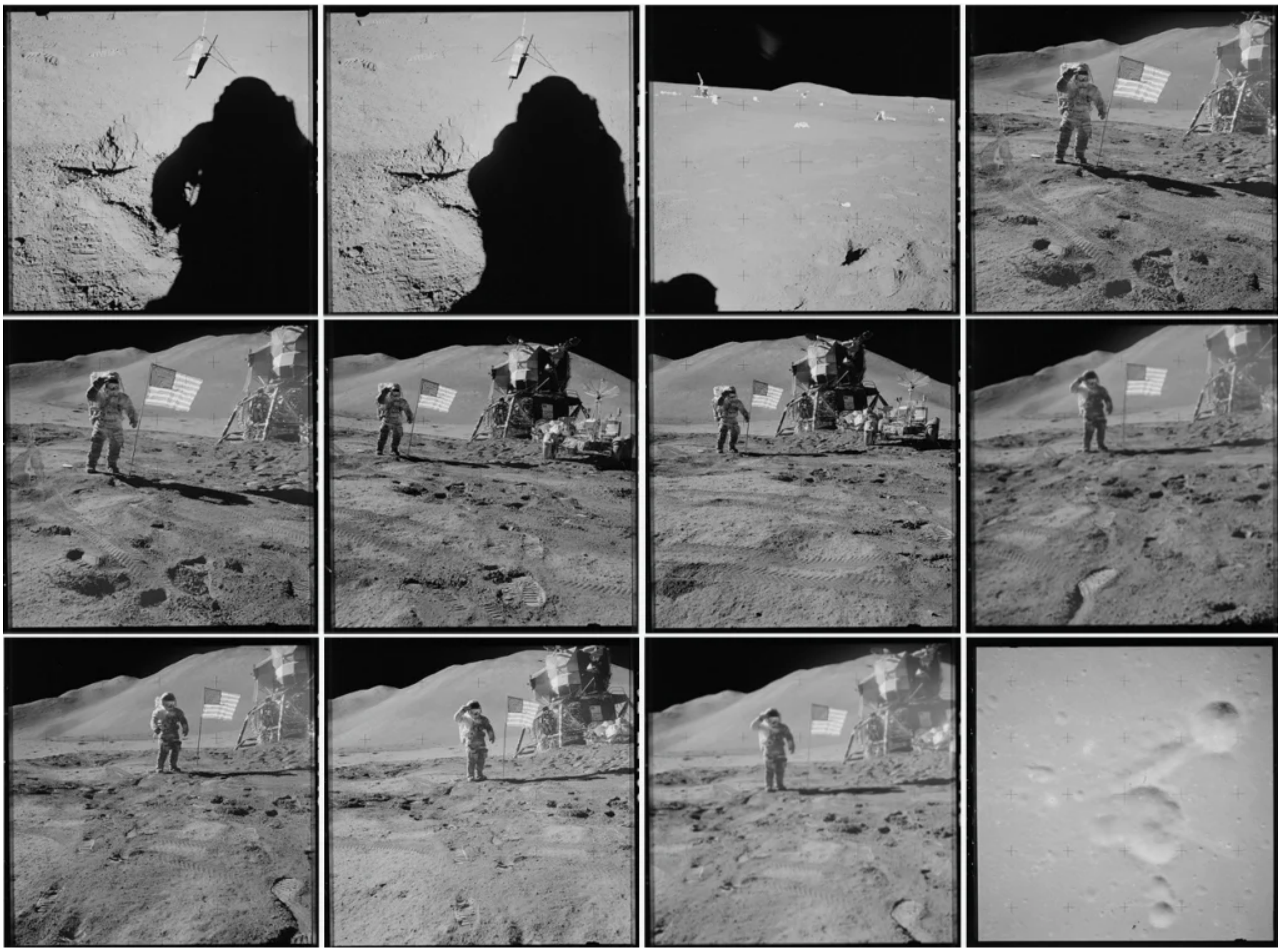
Do not judge strictly, this is our very first try!

Do not judge strictly, this is our very first try!

I really wanted to put an end here and finish the article, but I remembered that I had not yet answered one question that was in the comments. It sounded something like this: "And if the astronaut goes forward to the projector, he will end up in overexposure. The closer to the projector, the higher the illumination on the spacesuit. Why do we not see any overexposure on the lunar images?"

Dear friends! The fact that the illumination depends on the distance (two times closer came - the illumination increased four times, for point light sources) you know not only, but the employees of NASA also know it. Therefore, in the "lunar" images, where front projection is used, no one goes anywhere.

Here are 8 black-and-white shots with a moonlit mountain in the background, this is from the album "Apollo 15". I specially captured the frames that were BEFORE and AFTER the frames with front projection. The astronaut does not move anywhere. In addition, there is a mannequin in the frame.



12 consecutive stills from the Apollo 15 album.

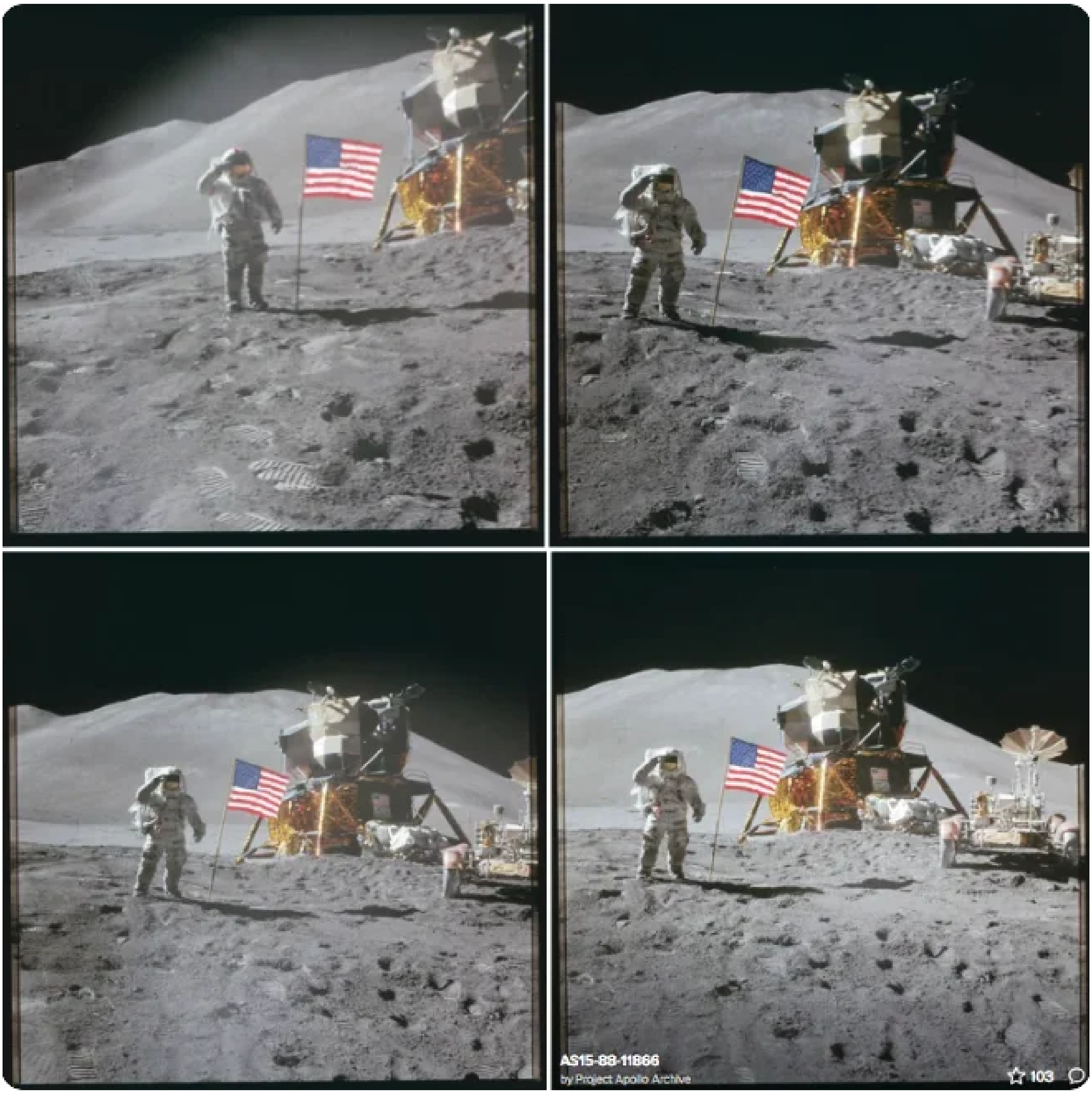
12 consecutive stills from the Apollo 15 album.

Logically, if the astronaut actually ended up on the moon and photographed his friend, then, moving away from the rocket, he would take several pictures sequentially: for example, first there would be a picture near the lunar module, then, after going a few steps, there would appear a series of shots with the astronaut in the foreground and the lunar module behind him, then, having retired a few more steps, the photographer would make a couple of general plans “for all mankind” with a small astronaut figurine and a lunar module in the distance. But we do not see such a sequence, instead, all the frames (and the same thing in other Apollo "expeditions") are shot in the same way from the same distance, in the same angle, and then, in the same specified frame boundaries the necessary "elements" fit in (put into the frame): a mountain in the background, a lunar module,

And in order not to illuminate the screen with the lunar mountain with a searchlight, the astronaut is illuminated with a device directed away from the screen with a back-side light.

To create the feeling that an astronaut with a camera is approaching or moving away from the subject of photography, they did what was practiced in the cinema: a large platform with the astronaut was moved relatively to a fixed screen.

The only thing the camera could do was pan slightly left or right. The width of the screen was 32 meters, and the frame included 23-24 meters. Therefore, the camera could make a left-right panorama about 1/3 of the frame width, no more.



Color photographs from the album "Apollo 15".

Color photographs from the album "Apollo 15".

The front projection reception in the "lunar" images betrays itself.

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Cameraman L. Konovalov was with you. Until next time!

a